Jack R. Benjamin and Associates, Inc.

Statement of Qualifications

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JBA Background

Jack R. Benjamin and Associates, Inc. (JBA) is an engineering consulting firm specializing in natural phenomena hazards analysis, structural and earthquake engineering and the application of probabilistic methods to address engineering, safety and management problems. JBA was formed in 1979 by a group of civil/structural engineers, including Dr. Jack R. Benjamin a leader in the application of probabilistic methods and decision theory. Dr. Benjamin is Professor Emeritus of Civil Engineering at Stanford University and co-author with Allin Cornell of the book: ***Probability, Statistics, and Decision for Civil Engineers***. At JBA a practical approach is applied to engineering problems, supported by extensive experience in state-of-the-art statistical and probabilistic modeling methods.

JBA is a leading consulting firm dedicated to providing quality engineering services. Services are tailored to meet client needs, ranging from full project support to serving in a general consultancy or advisory role. For all projects, JBA senior personnel are actively involved in all aspects of the work. Unlike most consulting firms, the senior personnel at JBA not only manage the project, they are heavily involved in the technical work. This provides JBA clients with the highest possible technical quality and the benefit of hands on project management.

On the following pages the range of JBA services is summarized and a list of representative projects is provided.

JBA General Services

JBA provides services in a wide range of areas that are centered around the civil/structural engineering background of the company and its extensive experience in the application of probabilistic methods to civil and structural engineering problems. JBA provides services in the following areas:

- Structural and seismic engineering
- Risk and reliability assessments for critical facilities (e.g., dams, lifelines, chemical facilities, power plants)
- Risk-based decision analysis
- Civil infrastructure risk management
- Structural standards development
- Statistical analysis and sampling methods
- Natural hazards assessment
- Natural hazards risk management
- Facility walkdown and vulnerability assessment
- Portfolio financial risk evaluation
- Independent reviews

For the past eighteen years JBA engineers have worked for government and regulatory agencies, private corporations, the electric utility industry and engineering construction firms. We approach each project with the objective of providing practical solutions with the highest technical quality.

Structural and Seismic Engineering Services

At JBA we strive to solve problems using cost-effective, reliable tools based on state-of-the-art knowledge and experience. Structural engineering services provided by JBA include:

- Dynamic structural analysis
- Design review of structural designs
- Soil-structure analysis
- Damage or vulnerability assessment
- Facility review and walkdown
- Development of performance-based design criteria

JBA engineers have been involved in the development and application of seismic vulnerability and walkdown methods applied in the nuclear industry. These procedures are an excellent guide for assessing vulnerabilities and are applicable to industrial and commercial facilities. In addition, they provide a basis for focusing engineering resources on those components that are important contributors to system failure.

Risk and Reliability Assessment

JBA engineers all have extensive experience in the application of risk and reliability methods to evaluate civil and structural systems. In the area of risk and reliability assessment, JBA services include:

- Structure reliability assessment
- Systems analysis, including event and fault tree analysis
- Development of risk-based performance goals
- Risk quantification

JBA engineers have performed risk or reliability assessments for a wide range of facilities. A sample includes:

- nuclear power plants
- chemical facilities
- dams
- levees
- crane system

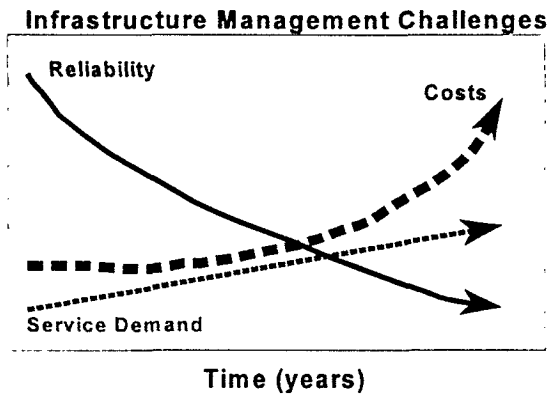
Our broad experience in the application of probabilistic methods provides us with the insight to focus a project on the critical issues. As an engineering tool, risk and reliability methods can be applied to varying levels of detail; as a scoping analysis or as part of a detailed assessment.

Civil Infrastructure Management

Management of a civil infrastructure (e.g., water distribution system, hydroelectric project, highways and bridges, etc.) is a complex balancing act. Factors such as increasing market competition, changing regulatory requirements, and tighter budgets, increase pressure on the owner/manager of an infrastructure to maintain reliable, cost-effective and productive facilities. This task is compounded by the cumulative effects of aging, and possibly, years of neglected maintenance.

Infrastructure management is a balancing act, complicated by a number of competing factors that include:

- demand for increased services or production,
- requirements for increased system reliability (e.g., reduced down-time),
- regulations requiring improved worker and public safety,
- pressure to reduce the cost of operations (e.g., maintenance activities),



- wear-out and deterioration that challenge/reduce system integrity and that accompany obsolescence of an infrastructure, and
- increased fiscal pressure (i.e., do more with less).

JBA engineers can work with management and your technical staff to develop a decision-support system that facilitates infrastructure management. A decision-support system based on a facility reliability assessment can be used to set and meet performance goals (i.e., reliability and service) and minimize costs. Applications of a reliability-based management system include:

- life-cycle assessment,
- short- and long-term budget projections, and
- scheduling of component inspections, maintenance, and replacement.

A decision support system is a valuable engineering-management tool to maintain reliable services and facility availability, while also controlling costs.

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Seismic Risk Assessment

An important part of earthquake engineering and the management of resources is the effective evaluation of the risk posed by seismic events. In order to make informed decisions, engineers, government officials, and company executives require a realistic assessment of the likelihood that earthquakes may lead to damage that will render a facility unusable or destroy it completely. The primary objective of a seismic risk assessment is to provide a realistic assessment of the potential damage (loss) that can occur during an earthquake and to assess this likelihood. Services provided by JBA in this area include:

- Evaluation of the performance of critical facilities such as dams, power plants, etc. during an earthquake
- Seismic fragility assessment for structures and equipment
- Lifeline (e.g., water, power, communication systems) risk assessment
- Regional (e.g., city, country) assessment of future earthquake losses
- Portfolio financial risk evaluation for future insurance losses
- Comparative risk assessments as part of design decisions, site selection, etc.

JBA has developed software tools for performing seismic risk evaluations. These tools combine the frequency of earthquake occurrences, estimates of the conditional probability of failure of structures and components to earthquake ground motion (or other hazards) and a system logic model to estimate the frequency of system failure. Our software has extensive output capability to examine intermediate as well as final results. We have also developed software to evaluate the performance of lifeline systems. This software accounts for the spatial distribution of system components to estimate the likelihood of failure.

Probabilistic Risk Assessment for Nuclear Stations

For over sixteen years, JBA engineers have been involved in the conduct and review of probabilistic risk assessments for nuclear stations. These projects have involved seismic, wind and flood assessments. As part of these assessments JBA engineers have performed the probabilistic hazards assessment, the structural and equipment fragility evaluations, systems modeling and risk quantification.

JBA services in this area are:

- seismic response assessment for the development of floor response spectra and the determination of structure fragility parameters
- seismic, wind (including tornado) and flood probabilistic hazards assessment
- structure and equipment fragility assessments
- walkdowns for seismic, wind and flood hazards
- risk quantification (assessment of the frequency of failure)

In recent years JBA has been involved in the performance of seismic and flood IPEEE evaluations for nuclear power stations. Responsibilities in these studies have included the performance of structural fragility and margin evaluations, systems modeling and risk quantification.

Representative List of Clients

- Electric Power Research Institute
- Pacific Gas and Electric Company
- Science Applications International Corporation
- Westinghouse Savannah River Company
- U.S. Navy
- Sandia National Laboratory
- Brookhaven National Laboratory
- Lawrence Livermore National Laboratory
- General Electric Company
- Stevenson and Associates, Inc.
- U.S. Army Corps of Engineers
- International Business Machines Corporation
- Klohn-Crippen Intg. (BC Hydro)
- Earth Science Associates, Inc. (Sacramento Flood Control Agency)
- GEI Consultants, Inc. (San Diego Water Authority)
- Bechtel Corporation
- Southern Company Services, Inc.
- Tennessee Valley Authority
- California Department of Water Resources
- Utah Emergency Management Agency
- EG&G Rocky Flats
- Martin Marietta Corporation
- Stanford University
- Obayashi Corporation
- Center for Nuclear Waste Regulatory Analysis
- Risk Management Solutions, Inc.

List of Typical JBA Seismic Engineering & Risk Assessment Projects

B.C. Hydro - Seven Mile Dam Assessment
Currently Dr. McCann is a consultant and reviewer for a risk assessment being conducted for Seven Mile Dam. The study is considering all hazards the dam may be exposed to and the performance of mechanical and electrical equipment as well as civil structures. Dr. McCann is assisting with the methodology to be used in the study, the review of the program scope and task statements, and the development of logic models to be used in the analysis.

Folsom Dam Reliability Assessment
Following the tainter gate failure at Folsom Dam, Dr. McCann was retained by the Sacramento Area Flood Control Agency (SAFCA) to prepare an initial work scope and budget for a reliability assessment for Folsom Dam.

San Diego Water Authority
As part of a planning study, the San Diego County Water Authority (SDCWA) considered alternative designs for an Emergency Storage Project (ESP). To support this study, an evaluation was conducted in which a safety goal (SG) for the performance of dams was recommended. The SG established a minimum performance and reliability levels for dams that are considered as part of alternative ESP system designs. Once the SG was selected, the risk assessment focused on the characteristics that must be provided by the design of a dam so that a reasonable assurance exists that the SG is in fact met. As an example, for seismic events the risk assessment determined the ground motion level that a dam must be capable of withstanding in order to provide the required level of reliability.

Par Pond Dam
At the request of Westinghouse Savannah River Company, JBA engineers under the direction of Dr. McCann, conducted a preliminary risk assessment for Par Pond Dam. The risk study was conducted as part of an extensive safety evaluation of this high hazard dam. The evaluation included an assessment of seismic, hydrologic and geotechnical risks of failure.

Flood Hazard Assessment - Hanford, Washington
JBA conducted a probabilistic flood hazard evaluation for the U.S. Department of Energy's N-Reactor. As part of this assessment the potential for flooding due to upstream dam failure was considered. Event trees were developed to consider the possible combination of dam failures in the U.S. and Canada. This was the first study to route dam break floods for dams in Canada into the U.S.

Lock and Dam Risk Assessments
Working for the U.S. Army Corps of Engineers, JBA conducted a probabilistic risk assessment for lock and dam systems on the Ohio River. These studies evaluated the likelihood of events that would lead to closure or unavailability of the locks to service traffic. The risk assessment considered structure failures (e.g., dam failure, lock wall failure), mechanical or structural gate failures, barge accidents, etc. For purposes of projecting the results of the risk assessment over a 25-year period, the effect of concrete deterioration on lock wall integrity was considered.

Federal Emergency Management Central U.S. Six Cities Study
Working for the Federal Emergency Management Agency, JBA engineers participated in the central U.S. six cities study. The purpose of this project was to perform a seismic vulnerability assessment for six cities that would be impacted by a major earthquake in the New Madrid seismic zone. In this study JBA assisted in the evaluation of transportation, water and power systems. In addition, JBA performed vulnerability assessments for a wide range of structures and equipment items, including electric power systems, dams, residential construction, commercial buildings, highway bridges, etc.

Utah Multi-Hazards Assessment
Working for the Utah Emergency Management Agency, JBA performed a probabilistic assessment of the seismic and geologic hazards that may impact the city of Ogden, Utah. The assessment included and evaluation of the potential damage in the event of specified scenario earthquakes on the Wasatch Fault. The assessment considered the damage associated with earthquake ground motion and flooding that could result in the event of an upstream dam failure. The study included an assessment of structural damage, injuries and fatalities.

Probabilistic Risk Assessments for Savannah Reactors
Working for Westinghouse Savannah River Company, JBA assisted in the probabilistic risk assessment studies performed for reactors at the Savannah River site. In these studies JBA conducted an evaluation of the seismic hazard at the site, assessed the probability of failure of structures, equipment and underground piping to earthquake ground motion and ground settle-ments, assisted in the developed of reactor systems models and quantified the risk of reactor failure to seismic events. JBA provided engineering services to Westinghouse for six years.

U.S. Chemical Weapons Facilities
As part of quantitative risk assessments performed for U.S. Army Chemical Demilitarization Facilities, JBA conducted seismic walkdowns, probabilistic vulnerability assessments and probabilistic seismic hazard assessments for structures and equipment items that are a part of the chemical demilitarization process. In addition, this study also examined the vulnerability of concrete and steel weapons storage structures and of stockpiled weapons. The purpose of this study was to assess the likelihood that seismic events could initiate an accident leading to the release of chemical agents.

JBA Risk and Hazard Assessment Software Tools

As part of our project experience, JBA engineers have developed software tools or modified existing programs to perform computations required as part of probabilistic risk and hazard assessment computations. These software packages include:

- FL_HAZ - Probabilistic flood hazard assessment (developed by JBA)
- JBA_LIFE - Lifeline risk assessments
- SHIP - Systems based risk quantification software (developed by JBA)
- JBA_HAZ - Seismic hazard assessment software

A summary of these codes is provided below.

FL_HAZ - This software package was developed by JBA to perform comprehensive flood hazard calculations. The purpose of this software package is estimate the frequency of exceedance of flood stage levels at a site. The accompanying figure shows the basic steps in the assessment.

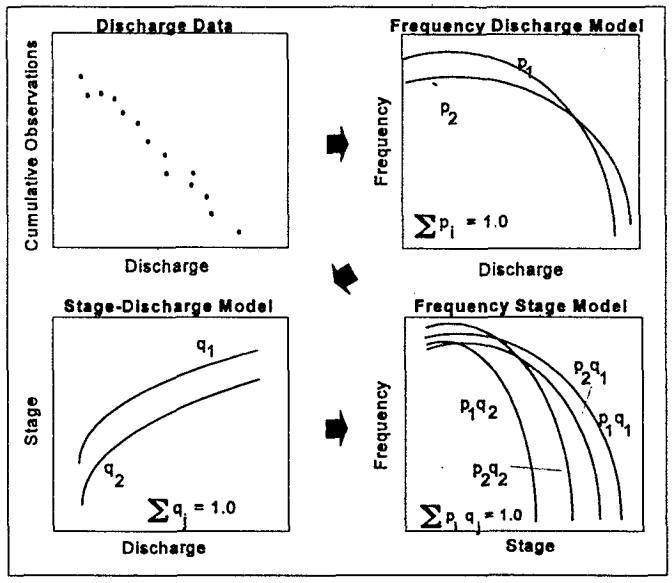


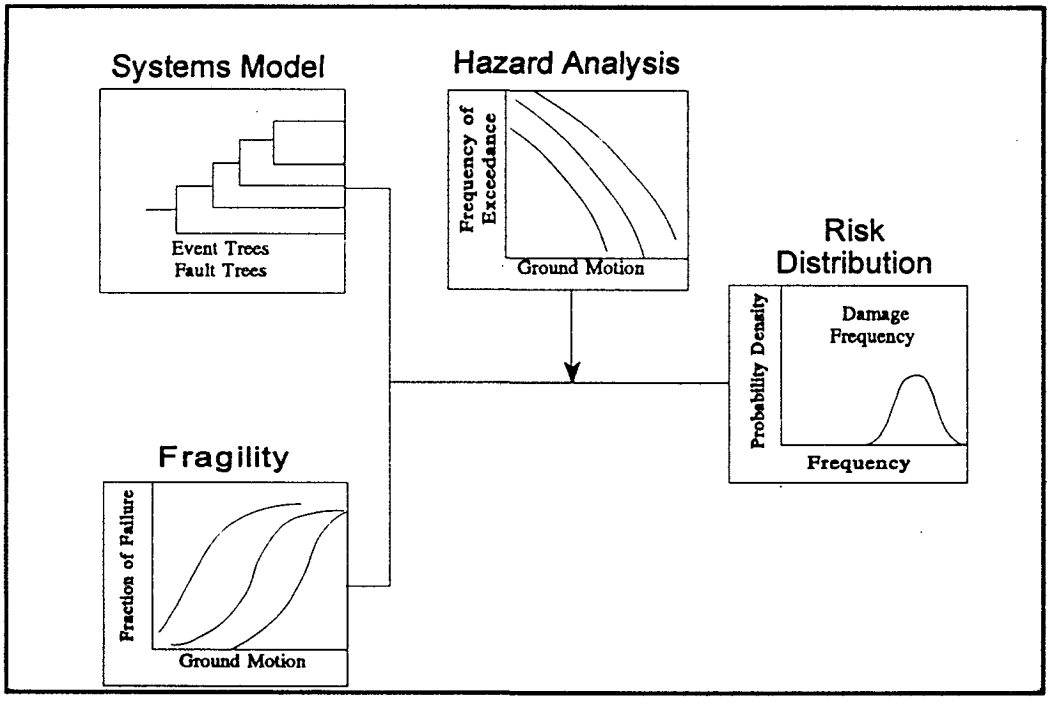
Illustration of the steps to quantify the epistemic uncertainty in flood stage.

The code was specifically designed to take into account the epistemic (knowledge-based) and aleatory (random, inherent) uncertainty in flood hazard assessments. Epistemic uncertainties include those associated with the length of the historic record and choice of the flood frequency model. These uncertainties can be modeled in FL_HAZ to develop a composite estimate of the frequency of flooding. The result of this software is a series of flood stage hazard curves that quantify the frequency of exceedance of flood discharge and stage as well as the uncertainty in these frequency estimates.

SHIP - SHIP was developed by JBA to perform probabilistic risk assessment calculations for civil infrastructure systems exposed to natural hazards such as seismic, wind and flood events. The program accepts as input:

- site hazard information (e.g., flood frequency curve, seismic hazard curve),
- component vulnerability data (e.g., fragility curves), and
- systems logic model (e.g., event tree and/or fault trees).

SHIP uses these inputs to assess the frequency of system failure and to provide the engineer with insights to the dominant failure modes of a system. The accompanying figure shows the elements of a SHIP evaluation for seismic events.



Unique features of SHIP include:

- the capability to propagate epistemic and aleatory uncertainties to the final results,
- the capability to analyze system logic models (e.g., event and fault trees), and
- an algorithm to solve system fault trees correctly, without simplifying assumptions.

The program is designed to provide a wide range of intermediate and final results to support the engineer's efforts to understand the performance of a system. SHIP has undergone a Quality Assurance review that meets the requirements of 10 CFR Part 50, Appendix B.

JBA_LIFE - To evaluate the performance of spatially distributed systems (e.g., water supply systems), JBA engineers modified an existing program developed at MIT to produce JBA_LIFE. It includes the capability to model the functional logic of a lifeline system (e.g., network logic that defines the system operation) and the spatial variation of a hazard (e.g., earthquake ground motion, flooding) to evaluate a system or network reliability. A system can be defined in terms of components that are spatially distributed (e.g., a levee system, pipeline) or located at a point (e.g., a pump station). The reliability of components in the system can be defined in terms of a rate of failure (e.g., rate per length) or a in terms of a probability distribution.

The code solves the system logic to determine the probability of failure of the system to survive specific event. JBA_LIFE can also be used to evaluate the annual frequency of system failure for the range of future random events that can occur (e.g., flooding of different magnitudes, seismic events).

Seismic Hazard Software - JBA has two primary codes available to perform probabilistic seismic hazard assessments. We are a licensed user of the Electric Power Research Institute's seismic hazard software package, EQHAZARD. This package is generally applicable to sites located in intraplate regions such as the central and eastern U.S. For sites in the western U.S. and elsewhere, we have modified an existing code developed at Stanford University. This software package, JBA_HAZ, has the following capabilities:

- model seismic sources as three dimensional fault planes as well as line and area sources,
- suite of ground motion attenuation models to choose from,
- use a characteristic model to evaluate the frequency of earthquake occurrences,
- model the epistemic and aleatory sources of uncertainty, and
- generate deaggregated hazard results to easily evaluate the contribution of different seismic sources to the site hazard and different size earthquakes to the total hazard.

Recently, this software was used to evaluate the seismic hazard at a site in Japan where subduction zone sources as well as other, shallow tectonic features were modeled.

Resumes of JBA Principals

RESUME OF MARTIN W. McCANN, JR.
President, Jack R. Benjamin & Associates, Inc.

Education

B.S. - Civil Engineering, Villanova University, 1975
M.S. - Structural Engineering, Stanford University, 1976
Ph.D. - Civil Engineering, Stanford University, 1980

Memberships

American Society of Civil Engineers
Association of State Dam Safety Officials
United States Committee on Large Dams
Society for Risk Analysis
American Geophysical Union
Earthquake Engineering Research Institute
Seismological Society of America

Committees

ASDSO Scholarship Committee
ASDSO Affiliate Member Advisory Committee
American Nuclear Society - ANS-2 Site Evaluation
American Nuclear Society - ANS-2.29 Subcommittee Chairman - Probabilistic Analysis of Natural Phenomena Hazards for Nuclear Materials Facilities

Awards

1994 Engineering News-Record - Newsmaker
1995 Association of State Dam Safety Officials - Presidents Award

Experience

Jack R. Benjamin & Associates, Inc., Mountain View, CA (since 1979)

Dr. Martin W. McCann, Jr. is President of Jack R. Benjamin & Associates, Inc. From 1984 to 1989 he served as Vice President of the corporation. His professional background includes probabilistic hazards analysis, including seismic and hydrologic events and probabilistic structural analysis.

Dr. McCann recently assisted EPRI in developing an industry position regarding the seismic design basis for future nuclear power plants. As part of this effort, Dr. McCann is working with industry representatives and the USNRC to develop an effective, stable approach for seismic siting.
Dr. McCann was the project manager of a study to evaluate the risk of failure of three lock and dam

structures on the Upper Ohio River. This study was concerned with a 25-year projection of the frequency of the loss of function of the navigation locks due to natural and man-made hazards.

Dr. McCann directed a preliminary probabilistic risk assessment for PAR Pond Dam at the Department of Energy Savannah River Site. The study included an assessment of the frequency of dam failure due to seismic, hydrologic, and static load events.

As part of a DOE, industry and EPRI study to evaluate future reactor designs, Dr. McCann performed an extensive hazard assessment for the eastern U.S. In this analysis the seismic hazard was mapped for the entire eastern U.S. at a grid spacing of 25 km. These hazard results were used to map the risk of a future nuclear power plant located anywhere in the east.

Dr. McCann was the project manager of a program to conduct an independent review of the EPRI seismic hazard software package, EQHAZARD. Following completion of the software review, JBA maintains the codes for EPRI according to Quality Assurance Standards.

As part of the Department of Energy (DOE) and Lawrence Livermore National Laboratory (LLNL) natural phenomena hazards project, Dr. McCann prepared the flood design criteria in Design and Evaluation Guidelines For Department of Energy Facilities Subjected to Natural Phenomena Hazards, UCRL-15910. He was the course lecturer for the flood part of the DOE workshop on natural phenomena hazard. The workshop addresses the DOE flood design guidelines, probabilistic flood hazard assessment and flood design strategies.

Dr. McCann was the project manager of an effort supported by LLNL to review the potential flood hazards at DOE facilities in the U.S. The principal objective of this work is to conduct a preliminary, cost-effective review in order to screen those sites that may require an in-depth probabilistic flood hazard analysis. The results of this preliminary effort are a series of recommendations to minimize the risk at each DOE site due to flood hazards. Preliminary flood hazard studies have been performed for nine DOE sites.

Under the direction of Dr. McCann, JBA performed a probabilistic flood hazard assessment for the DOE Hanford Reservation, located adjacent to the Columbia River. The flood hazard assessment considered the possibility of extreme flood events and upstream dam failure as potential causes of onsite flooding.

As a subcontractor to Sandia National Laboratories for the USNRC Unresolved Safety Issue on Decay Heat Removal, JBA performed probabilistic flood studies at a number of nuclear power plant sites. These studies involved an assessment of the frequency of extreme floods and the frequency of core damage.

Dr. McCann was the project manager of an Electric Power Research Institute (EPRI) sponsored study to evaluate the engineering characteristics of small-magnitude earthquakes. As part of this study the threshold level of ground motion required to damage nuclear power plant structures and equipment was estimated.

As part of a study at the DOE Savannah River Site, Dr. McCann was the project manager of a program to evaluate the risk to nuclear reactor facilities due to seismic events. JBA is providing the seismic hazard and fragility input to the risk assessment. In addition, JBA is conducting the risk quantification calculations, using software developed at JBA. For the Savannah River Site, Dr. McCann conducted an extensive comparative evaluation of the EPRI and LLNL seismic Hazard assessments. This study, which involved extensive modification of the EPRI and LLNL seismic hazard software identified the source of the differences between the two studies and developed a single, composite estimate of the site hazard.

Working for Southern Company Services, a similar comparative evaluation was performed for Plant Farley.

Dr. McCann participated in a project to develop a USNRC external event PRA procedures guide and a review document for seismic and external flood hazards.

Department of Civil Engineering, Stanford University (since 1981) - Consulting Professor

Currently, Dr. McCann is the chairman of the National Performance of Dams Program (NPDP) Executive Committee. The NPDP is headquartered at Stanford. The program operates and maintains a library and database on dam incidents. The library contains over 6,000 documents, including the U.S. Committee on Large Dams incident files. The library and database will serve as a valuable resource for engineers to evaluate dam operating experience.

Working with the Association of State Dam Safety Officials, Dr. McCann was a chairman of a committee to develop a national standard for reporting the performance of dams. The result of this work was the publication of the Guidelines for Reporting the Performance of Dams.

Dr. McCann was the director of a project to develop probabilistic risk analysis procedures for the evaluation of dams. The project was supported under a contract with the Federal Emergency Management Agency (FEMA). The objectives of the project included the development of a probabilistic screening procedure to assign priorities to dams in a jurisdiction based on a cost-effectiveness criteria. A methodology to conduct a detailed probabilistic risk analysis of existing dams due to all stimuli was also developed.

As part of the FEMA project, Dr. McCann has presented workshops on the probabilistic assessment of dams in the U.S. and in foreign countries.